FILTER SYSTEM WITH FILTER MEANS RETRACTABLE INTO A HOUSING

The present invention relates to a filter system for
use in a reactor. In particular, the invention relates to
filter system suitable for a reactor to be used for
exothermic reactions such as Fischer-Tropsch reactions,
as well as to hydrocarbons and fuels derived from these
hydrocarbons which can be made by the hydrogenation of
carbon monoxide in a process using the reactor and the
filter system.

The Fischer-Tropsch process is often used for the
conversion of hydrocarbonaceous feed stocks into liquid
and/or solid hydrocarbons. The feed stock (e.g. natural
gas, associated gas, coal-bed methane, residual (crude)
oil fractions and/or coal) is converted in a first step
into a mixture of hydrogen and carbon monoxide (this
mixture is often referred to as synthesis gas). The
synthesis gas is then fed into a reactor where it is
converted in a second step over a suitable catalyst at
elevated temperature and pressure into paraffinic
compounds ranging from methane to high molecular weight
molecules comprising up to 200 carbon atoms, or, under
particular circumstances, even more.

Numerous types of reactor systems have been developed
for carrying out the Fischer-Tropsch reaction. For
example, Fischer-Tropsch reactor systems include fixed
bed reactors, especially multi tubular fixed bed
reactors, fluidised bed reactors, such as entrained
fluidised bed reactors and fixed fluidised bed reactors,
and slurry bed reactors such as three-phase slurry bubble
columns and ebulated bed reactors.

The Fischer-Tropsch reaction is very exothermic and
temperature sensitive with the result that careful
temperature control is required to maintain optimum
operation conditions and desired hydrocarbon product
selectivity.

The heat transfer characteristics of fixed-bed
reactors are generally poor because of the relatively low
mass velocity, small particle size and low thermal
capacity of fluids. If one attempts, however, to improve
the heat transfer by increasing the gas velocity, a
higher CO conversion can be obtained, but there is an
excessive pressure drop across the reactor, which limits
commercial viability. In order to obtain the CO
conversions desired and gas through-puts of commercial
interest, the conditions result in substantial radial
temperature gradients. For that reason, the Fischer-
Tropsch fixed-bed reactor tubes should have a diameter of
less than 5 or 7 cm to avoid excessive radial temperature
profiles. The desired use of high-activity catalysts in
Fischer-Tropsch fixed-bed reactors makes the situation
even worse. The poor heat transfer characteristics make
local runaways (hotspots) possible, which may result in
local deactivation of the catalyst. In order to avoid
runaway reaction the maximum temperature within the
reactor must be limited. However, the presence of
temperature gradients within the reaction mixture means
that much of the catalyst may be operating at sub-optimal
levels.

The use of liquid recycles as a means of improving
the overall performance in a fixed-bed design has been
described. Such a system is also called a "trickle bed"
reactor (as part of a sub set of fixed-bed reactor
systems) in which both reactant gas and liquid are

introduced (preferably in an up flow or down flow
orientation with respect to the catalyst) simultaneously.
The presence of the flowing reactant gas and liquid
improves the reactor performance with respect to CO
conversion and product selectivity. A limitation of the
trickle bed system (as well as of any fixed-bed design)
is the pressure drop associated with operating at high
mass velocities. The gas-filled voidage in fixed-beds
(typically less than 0.50) and size and shape of the
catalyst particles does not permit high mass velocities
without excessive pressure drops. Consequently, the mass
through-put undergoing conversion per unit reactor volume
is limited due to the head transfer rates. Increasing the
individual catalyst particle size may slightly improve
the heat transfer by allowing higher mass velocities (for
a given pressure drop), but the loss in selectivity
towards the high boiling point products and the increase
in methane selectively combined with the increase in
catalyst activity generally offset the commercial
incentives of higher heat transfer.

Three-phase slurry bubble column reactors generally
offer advantages over the fixed-bed design in terms of
heat transfer characteristics. Such reactors typically
incorporate small catalyst particles suspended by upward
flowing gas in a liquid continuous matrix. A plurality of
cooling tubes are present in three phase slurry reactors.
The motion of the continuous liquid matrix allows
sufficient heat transfer to achieve a high commercial
productivity. The catalyst particles are moving within a
liquid continuous phase, resulting in efficient transfer
of heat generated from catalyst particles to the cooling
surfaces, while the large liquid inventory in the reactor
provides a high thermal inertia, which helps prevent

rapid temperature increases that can lead to thermal
runaway.

A number of ways have been proposed to separate
liquid, especially liquid hydrocarbons reaction products
produced in a Fischer Tropsch reaction, from the slurry
in a three phase slurry reactor.

Thus, European patent application 609 079 describes a
slurry bubble column containing a slurry bed of catalyst
particles suspended in a liquid. A filtration zone is
located in the slurry bed, in particular close to the
upper surface of the slurry bed. The filtration zone
typically comprises a plurality of filter elements. The
filter elements are typically of elongated cylindrical
form and comprise a cylindrical filtering medium
enclosing a filtrate collection zone. The filtration
results in the formation of a cake, which is removed by
back flushing.

European patent application 592 176 describes a
filtration zone consisting of a tube sheet holding filter
cartridges. The tube sheet defines the upper surface of
the slurry bed.

International (PCT) application No. 94/16807
describes a filtration zone surrounding the slurry bed.
No cake build-up is observed because a very low mean
pressure differential is used over the filter elements. A
critical value of 6 mbar is mentioned in the description.

UK patent application 2 281 224 discloses a reactor
containing a plurality of reaction tubes arranged to
accommodate the slurry bed. The upper part of each
contains a filter element to separate hydrocarbon product
slurry, and a top part of increased diameter, often
referred to as a disengagement zone, to separate gas from
the slurry.

US patent 5,324,335 describes the preparation of hydrocarbons using an (unsupported) iron catalyst. To avoid the continuous increase in slurry height in the reactor vessel, wax is separated from the slurry using a cross-flow filter located outside the reactor vessel. Filter cake is regularly removed by pressurising the filtered wax on the shell side of the filter with an inert gas to bump the cake into the slurry stream.

German patent 3,245,318 describes a process for separating a liquid product stream from a slurry, by cross-flow filtration, which is carried out at substantially reactor pressure, but outside the reactor. Regular back flushing of the filter medium by reversal of the pressure over the filter element is necessary.

US patent 6,344,490 describes a three phase slurry bubble column comprising one or more filter assemblies suspended in a slurry. The construction of the reactor and the filter assemblies is such that each assembly can be removed via an opening in the top of the reactor. From the description it is clear that the chance is done at ambient pressure. Thus, in the case that one or more filters need to be replaced in the process according to US 6,344,490, the process needs to be stopped, the reactor needs to be depressurised, and a restart (at high pressure and high temperature) needs to be done. For a large commercial slurry reactor it will take several hours to cool down the reactor by 75-100 °C, depressurisation, filter exchange, repressurisation and heating up by 75-100 °C.

The present invention provides a filter system for use in a reactor, the filter system having filter means to separate fluid from a mixture of particulate matter and fluid, and having a filter housing adapted to connect

to the reactor and adapted to receive the filter means, wherein the filter means is retractable into the housing.

The advantage of the present invention is that it is not needed any more to stop the process, cool down the inventory and to pressurise and heat up the reactor till the reaction temperature. Suitably the reaction temperature is decreased by 25-75 °C, i.e. just sufficient to stop the reaction. The amount of synthesis gas introduced in the reactor may be decreased by up to 75%. At least 10%, preferably about 20% is usually still introduced in the reactor in order to keep the catalyst particles in suspension. The remaining syn gas stream may be replaced by another gas, e.g. an inert gas as nitrogen or by a recycle stream. Preferably the reaction the reactor temperature is decreased by less than 25 °C, preferably less than 10 °C, and the reaction is continued at the same productivity as the continuous productivity.

The filter means is typically retractable through an aperture in the reactor, typically on an upper surface of the reactor, especially the top of a large tubular reactor as depicted in Figure 1. The housing is typically detachably connected to the aperture.

Typically the filter means has an export conduit leading from the filter means, to deliver filtrate from the filter means to processing equipment outside the reactor. The filter means may optionally have a connector for a hoist line, to facilitate retraction of the filter means into the housing, or simply may be retracted via the export conduit. The hoist line or the export conduit may be activated to pull the filter means into the housing from the reactor.

Typically the housing has an outlet for removing the filter means therefrom. In certain embodiment the housing

can have an outlet port at the top or at a side though
which the filter can be removed from the housing, or in
more simple embodiments the housing is detachable from
the reactor, so that the filter can be removed via the
aperture used to retract the filter into the housing. A
suitable housing is an elongated tube or pipe, preferably
provided with detachable closing and/or sealing devices.

The housing preferably has at least one sealing
device such as a valve for sealing the aperture between
the reactor and the housing, so that when the filter
means is retracted within the housing past the aperture,
the sealing device can be actuated to seal the aperture
and isolate the housing from the reactor. This permits
the subsequent removal of the filter means from the
housing, and de-pressurisation of the housing, without
de-pressurising the reactor.

Typically the filter means is lowered under gravity
through an aperture in the upper surface of the reactor.
When in use, the filters preferably are situated below
the surface level of the expanded slurry bed.

In certain embodiments, the filter means can be
provided with a cap adapted to prevent settling of fines
on the filter means, and this is typically achieved by
providing the cap with a sloped upper surface, so as to
reduce the horizontal surface area presented by the
filter means. In practice, conical or frusto-conical caps
are preferred, with steep slopes so that fines of
catalyst that settle on the top of the cap generally
slide off and are dispersed into the slurry, and do not
settle on the cap. This reduces the tendency of solid
particles of catalyst to settle on the top of the filter
means, which has the advantage that there is a reduced
risk of uncontrolled exothermic reactions between the

slurry and the localised build-up of catalyst on the top
of the filter caps.

According to a further aspect, the invention provides
a method of removing a filter from a reactor, the method
comprising the steps of providing a filter housing
communicating with the reactor through an aperture,
retracting the filter from the reactor through the
aperture and into the filter housing, and sealing the
aperture between the reactor and the housing.

Typically the filter is removed from the housing
after the aperture has been sealed, in order to maintain
the integrity of the pressure in the reactor. Optionally
the housing can be pressurised to match the internal
pressure of the reactor before the aperture to the
reactor is opened, to replace the retracted filter with a
new one.

Especially when a number of filter systems e.g. 2-16,
especially 4-12, are present in one reactor, and the
total filtration capacity of all filter systems is more
than the required filtration capacity in view of the
production, there is the possibility to change filters
without the need to stop the reaction. In view of the
installed filtration overcapacity, one or even more
filters may be removed and replaced by new and/or
repaired filters. Especially in view of the large
productivity of commercial Fischer-Tropsch reactors -
such reactors will have a production capacity of 10.000-
20.000 bll/day - it is clear advantage to be able to
continue the production of hydrocarbons from synthesis
gas rather than to have to stop the reactor,
depressurisation of the reactor, followed by a restart of
the chemical process (CO hydrogenation).

In a preferred embodiment the filter is replaced by
pressurisation of the filter housing until the pressure
is the same as the reactor pressure and cooling down the
reactor up till 100 °C, suitably by 25-75 °C, followed by
opening the aperture between the housing and the reactor,
retracting the filter from the reactor through the
aperture and into the filter housing and sealing the
aperture between the reactor and the housing, followed by
heating up the reactor by up till 100 °C, suitably
25-75 °C, and continuing the process. Preferably the
amount of gas which is introduced in the reactor is
decreased by 50%, preferably 75%. The synthesis gas may
be replaced partly or completely by nitrogen.

In a further preferred embodiment the filter is
replaced by pressurisation of the filter housing until
the pressure is the same as the reactor pressure,
followed by opening the aperture between the housing and
the reactor, retracting the filter from the reactor
through the aperture and into the filter housing and
sealing the aperture between the reactor and the housing.
In this embodiment the hydrocarbon synthesis process is
continued at the same temperature and pressure as before
the filter replacement. Suitably the reaction is
continued at a production rate of at least 25% of the
usual production rate, more preferably at at least 50% of
the usual production rate.

It will be understood that after closing of the
aperture between the housing and the reactor the filter
can be removed from the housing by depressurisation of
the housing, opening of the housing, preferably at the
top of the housing, and removal of the filter from the
housing.

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In the same way as described above, but in the reverse order, a new or repaired filter may be introduced in the reactor. The same preferred embodiments as described above apply also for the introduction of the new or repaired filter. Before pressurisation of the housing, the housing is flushed with an inert gas, e.g. nitrogen. Pressurisation can be done by means of an inert gas, e.g. nitrogen and/or hydrocarbon synthesis off gas.

Without wishing to be restricted to a particular embodiment, the invention will now be described in further detail with reference to the drawings in which:

Figure 1 is a side view of a general arrangement of a reactor having a filter system;

Figure 2 is plan view of the reactor of Fig. 1, showing the arrangement of filters around the pipework of the Fig. 1 reactor;

Figure 3 is a side view of a filter system of the Fig. 1 reactor;

Figure 4 is a side view showing the detail of the filter module; and

Figure 5 is a cross-sectional view of a filter module.

Turning now to Figure 1 a reactor 20 has an outer shell 21 defining a chamber into which reactants are delivered. The reactor in this embodiment is typically used for carrying out three-phase slurry reactions, such as for example Fisher Tropsch type reactions.

Since the Fischer-Tropsch reaction is exothermic, the reactor 20 houses a number of cooling modules 1 for delivering and circulating coolant through the circulation system of coolant pipes within the reactor shell 21. Heat is transferred from the slurry surrounding the cooling modules 1 to the coolant as it passes through

the circulation system of the module. Suitable coolants
will be known to the person skilled in the art and
include for example water/steam or oil based coolants.

Liquid phase reactants and solid particulate catalyst
are fed into the reactor chamber from feed pipes (not
shown), and gas phase reactants are delivered at the base
of the reactor. The bubbles of gas rise in the liquid
phase and interact with the solid particulate catalyst in
the liquid phase to form reaction products, which are
removed from the reactor. Gas phase products are
typically removed by cyclones (not shown), and the light
wax fractions that leave the reactor in gas phase can be
recovered by cooling/condensation. The heavier fractions
largely composed of liquid waxes comprising high-value
long-chain hydrocarbons are separated from the slurry by
filtration before being recovered for further processing.

The filter system comprises a number of filter
modules 30, typically arranged around the densely packed
cooling modules 1 (shown in outline in Fig. 2) preferably
around the periphery of the array of cooling modules 1.
8 filter modules 30 are shown in the Fig. 1 embodiment,
but the number of filter modules used can vary in
accordance with the circumstances. Typically 2-20,
preferably 4-10, filter modules 30 would be advantageous.
In a preferred embodiment the filters are used as in
pairs of filter arranged in a vertical assemblement, i.e.
one filter immediately above another filter. In this
situation a relative small housing can be used.

The type of filter selected is not crucial to the
invention, but in this embodiment, each filter module 30
comprises a pair of filter bundles 31 formed from woven
stainless steel gauze material. A useful configuration is
a "sandwich" construction achieved by sintering the

layers together, and the resultant material is then
formed into filter tubes 32 of OD 40 mm and length 4 m,
of which about 50-60 are arranged in each filter
bundle 31 around a central export conduit 33. Each filter
module 30 can comprise one or more filter bundles 31
connected in series or in parallel to a common export
conduit 33. One filter module 30 is shown in the
drawings.

The export conduit 33 carries the filtered wax
products through an outlet of the reactor for further
processing, and optionally supports the weight of the
filter module while it is suspended in the reactor.

The export conduit 33 passes intact through a flanged
aperture 35 in the upper surface of the reactor 20 and
through a filter housing 38 attached to the flanged
aperture 35. The export conduit 33 passes intact through
an iris gland at the top of the filter housing 38. The
filter housing 38 is disposed directly above the flanged
aperture and is connected to the flange via a valve 39,
which can be closed to seal the aperture and thereby
isolate the reactor 20 from the filter housing 38.
Filtered products passing through the export conduit 33
are passed to further processing equipment P.

The filter housing 38 is in the form of a long
cylinder slightly longer and wider than the filter
modules 30, so that a single filter module 30 can be
received within the housing 38 without obstructing the
subsequent sealing of the valve 39.

In operation, the filter modules 30 hang below the
apertures 35, and are suspended from the export lines 33
in the upper part of the reactor, but immersed in the
slurry, as shown on the right hand side of Fig. 1. In
normal operation, a layer of catalyst builds up on the

surface of the filter modules, and this helps the filtration process as clean wax is separated through the pores of the catalyst layer. The flow rate of wax through the export conduit 33 is controlled by creating and adjusting a pressure differential across the filter module 30. Continuous filtration can be achieved at various flow rates using appropriate pressure differentials, but those skilled in the art will appreciate the rates and pressure differentials may be varied in accordance with the filter type, surface area, viscosity of the fluids, and the various other characteristics of the system.

The location of the filter modules 30 at the top of the slurry zone in this embodiment gives various advantages. Notably, the local concentration of catalyst at the top of the slurry zone is less than at the bottom of the reactor, due to the tendency of the catalyst particles to settle under gravity in the slurry. This reduction of particulate matter in the area of the filter modules 30 reduces their tendency to block, and increases their useful life. In addition, filter modules 30 will displace cooling modules from the reactor space there is a risk of uncontrolled reactions occurring adjacent to the filter modules 30. Therefore, it is useful to site the filter modules 30 in an area of the slurry zone where the reactions can be limited by the naturally reduced concentrations of catalyst particles. Also, locating the filter modules 30 at the top of the slurry zone minimises the required length of the filter modules, and the export conduit 33 or hoist apparatus, thereby facilitating handling of the filter modules 30 during changeovers.

When a filter module 30 becomes blocked or damaged, or when the filtration rate falls, the pressure

differential across the module 30 can be reversed to blow
waxes or cleaning fluids back into the filter to clear
the blockage. This can be conducted regularly as part of
the normal operating procedures, and may improve the
filtration properties of the module in question, but at
some point the filter module 30 will need to be removed
from the reactor 20 for repair or replacement.

When a filter module is to be removed, the gas
injection into the reactor is optionally interrupted, the
pressure differential across the module 30 is removed or
reduced, and the export conduit 33 is withdrawn through
the iris gland at the top of the filter housing 38 to
retract the filter module 30 through the aperture at the
top of the reactor 20 and into the filter housing 38, as
shown on the left hand side of Fig. 1. At this point the
pressure in the filter housing 38 is equalised with the
pressure in the reactor. When the filter module 30 is
wholly within the housing 38, the valve 35 is closed to
seal off the aperture and isolate the filter housing 38
from the reactor 20. At that point the filter housing 38
can be removed from the flanged aperture at the top of
the reactor entirely, and the filter module 30 removed
therefrom. Alternatively, the housing 38 can remain
attached to the reactor, and the filter module can be
removed through a port (not shown) through the end or
side wall of the housing 38. The damaged filter module 30
can then be repaired and a replacement or repaired filter
module 30 can be positioned within the housing 38, still
with the valve 35 being kept closed to isolate the
reactor 20 from the housing 38. When the replacement
filter module 38 is in place in the housing 38, and the
housing is secured to the flange, housing 38 can be
pressurised up to the reactor pressure, the valve 38 can

be opened again, and the replacement filter module can be
lowered into the slurry zone as shown in the right hand
side of Fig. 1.

This permits changeover of filter modules to repair
or replace damaged or blocked filters without
depressurising or cooling the reactor 20. The temporary
cessation of gas injection is preferred (although not
essential), and recovery of waxes can continue in certain
circumstances through the remaining filters. Thus a
rolling programme of filter replacement can be
implemented without disturbing the production regime.

In some embodiments a number of export conduits can
pass through a single aperture 35, to service more than
one filter module 38 per aperture.

In some circumstances, fixed filters can also be
incorporated into the reactor, typically at positions in
the slurry zone below the removable filter modules 30.

The filter bundle 31 in each module 30 typically has
a conical cap 31c with a steep slope in order to reduce
the tendency of catalyst particles to settle on top of
the filter bundles 31.

In certain circumstances a back-up external
filtration system can be used, by diverting products
flowing through the export conduit 33 into an external
filtration loop, and back into the processing
equipment P.

Modifications and improvements can be incorporated
without departing from the scope of the invention. For
example, the average particle size of the catalyst
particles may vary between wide limits, depending *inter
alia* on the type of slurry zone regime. Typically, the
average particle size may range from 1 µm to 2 mm,
preferably from 1 µm to 1 mm.

If the average particle size is greater than 100 μm, and the particles are not kept in suspension by a mechanical device, the slurry zone regime is commonly referred to as ebulating bed regime. Preferably, the average particle size in an ebulating bed regime is less than 600 μm, more preferably in the range from 100 to 400 μm. It will be appreciated that in general the larger the particle size of a particle, the smaller the chance that the particle escapes from the slurry zone into the freeboard zone. Thus, if an ebulating bed regime is employed, primarily fines of catalyst particles will escape to the freeboard zone.

If the average particle size is at most 100 μm, and the particles are not kept in suspension by a mechanical device, the slurry zone regime is commonly referred to as a slurry phase regime. Preferably, the average particle size in a slurry phase regime is more than 5 μm, more preferably in the range from 10 to 75 μm.

If the particles are kept in suspension by a mechanical device, the slurry zone regime is commonly referred to as stirred tank regime. It will be appreciated that in principle any average particle size within the above ranges can be applied. Preferably, the average particle size is kept in the range from 1 to 200 μm.

The concentration of catalyst particles present in the slurry may range from 5 to 45% by volume, preferably, from 10 to 35% by volume. It may be desired to add in addition other particles to the slurry, as set out in for example European Patent Application Publication No. 0 450 859. The total concentration of solid particles in the slurry is typically not more than 50% by volume,

preferably not more than 45% by volume. One or more draft tubes may be used to improve the catalyst dispersion.

Suitable slurry liquids are known to those skilled in the art. Typically, at least a part of the slurry liquid is a reaction product of the exothermic reaction. Preferably, the slurry liquid is substantially completely a reaction product.

The exothermic reaction is a reaction which is carried out in the presence of a solid catalyst, and which is capable of being carried out in a three-phase slurry reactor. Typically, at least one of the reactants of the exothermic reaction is gaseous. Examples of exothermic reactions include hydrogenation reactions, hydroformylation, alkanol synthesis, the preparation of aromatic urthanes using carbon monoxide, Kölbel-Engelhardt synthesis, polyolefin synthesis, and Fischer-Tropsch synthesis. According to a preferred embodiment of the present invention, the exothermic reaction is a Fischer-Tropsch synthesis reaction.

The Fischer-Tropsch synthesis is well known to those skilled in the art and involves synthesis of hydrocarbons from a gaseous mixture of hydrogen and carbon monoxide, by contacting that mixture at reaction conditions with a Fischer-Tropsch catalyst.

Products of the Fischer-Tropsch synthesis may range from methane to heavy paraffinic waxes. Preferably, the production of methane is minimised and a substantial portion of the hydrocarbons produced have a carbon chain length of a least 5 carbon atoms. Preferably, the amount of C_5+ hydrocarbons is at least 60% by weight of the total product, more preferably, at least 70% by weight, even more preferably, at least 80% by weight, most preferably at least 85% by weight.

Fischer-Tropsch catalysts are known in the art, and typically include a Group VIII metal component, preferably cobalt, iron and/or ruthenium, more preferably cobalt. Typically, the catalysts comprise a catalyst carrier. The catalyst carrier is preferably porous, such as a porous inorganic refractory oxide, more preferably alumina, silica, titania, zirconia or mixtures thereof.

The optimum amount of catalytically active metal present on the carrier depends *inter alia* on the specific catalytically active metal. Typically, the amount of cobalt present in the catalyst may range from 1 to 100 parts by weight per 100 parts by weight of carrier material, preferably from 10 to 50 parts by weight per 100 parts by weight of carrier material.

The catalytically active metal may be present in the catalyst together with one or more metal promoters or co-catalysts. The promoters may be present as metals or as the metal oxide, depending upon the particular promoter concerned. Suitable promoters include oxides of metals from Groups IIA, IIIB, IVB, VB, VIB and/or VIIB of the Periodic Table, oxides of the lanthanides and/or the actinides. Preferably, the catalyst comprises at least one of an element in Group IVB, VB and/or VIIB of the Periodic Table, in particular titanium, zirconium, manganese and/or vanadium. As an alternative or in addition to the metal oxide promoter, the catalyst may comprise a metal promoter selected from Groups VIIB and/or VIII of the Periodic Table. Preferred metal promoters include rhenium, platinum and palladium.

A most suitable catalyst comprises cobalt as the catalytically active metal and zirconium as a promoter. Another most suitable catalyst comprises cobalt as the

catalytically active metal and manganese and/or vanadium as a promoter.

The promoter, if present in the catalyst, is typically present in an amount of from 0.1 to 60 parts by weight per 100 parts by weight of carrier material. It will, however, be appreciated that the optimum amount of promoter may vary for the respective elements which act as promoter. If the catalyst comprises cobalt as the catalytically active metal and manganese and/or vanadium as promoter, the cobalt : (manganese + vanadium) atomic ratio is advantageously at least 12:1.

The Fischer-Tropsch synthesis is preferably carried out at a temperature in the range from 125 to 350 °C, more preferably 175 to 275 °C, most preferably 200 to 260 °C. The pressure preferably ranges from 5 to 150 bar abs., more preferably from 5 to 80 bar abs.

Hydrogen and carbon monoxide (synthesis gas) is typically fed to the three-phase slurry reactor at a molar ratio in the range from 0.4 to 2.5. Preferably, the hydrogen to carbon monoxide molar ratio is in the range from 1.0 to 2.5.

The gaseous hourly space velocity may vary within wide ranges and is typically in the range from 1500 to 10000 Nl/l/h, preferably in the range from 2500 to 7500 Nl/l/h.

The Fischer-Tropsch synthesis is preferably carried out in a slurry phase regime or an ebulating bed regime, wherein the catalyst particles are kept in suspension by an upward superficial gas and/or liquid velocity.

It will be understood that the skilled person is capable to select the most appropriate conditions for a specific reactor configuration and reaction regime.

Preferably, the superficial gas velocity of the synthesis gas is in the range from 0.5 to 50 cm/sec, more preferably in the range from 5 to 35 cm/sec.

Typically, the superficial liquid velocity is kept in the range from 0.001 to 4.00 cm/sec, including liquid production. It will be appreciated that the preferred range may depend on the preferred mode of operation.

According to one preferred embodiment, the superficial liquid velocity is kept in the range from 0.005 to 1.0 cm/sec.